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**LIGHTING AND OTHER PERCEIVABLE EFFECTS FOR TOYS AND OTHER
CONSUMER PRODUCTS**

5 **Cross-references to Related Application**

The present application claims the benefit, under 35 U.S.C. §119(e), of U.S. Provisional Application Serial No. 60/427,805, filed November 20, 2002, entitled "Multiple Modality I/O System for Whirling Toy," which application hereby is incorporated herein by reference.

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Background

Lighting elements are sometimes used to illuminate various items, such as a consumer product, wearable accessory, toy, novelty item, or the like. The lighting associated with such items often enhances the pleasurable experience associated with observing, playing with, wearing or otherwise using the item.

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Summary

Various embodiments of the present invention are directed generally to toys or other consumer products that are configured to provide one or more output modalities/conditions that may be sensed or perceived by a human (e.g., light and/or sound) to facilitate some form of interactivity between the toy/product and one or more users/observers of the toy/product. In one embodiment, the toy/product also may be configured to monitor one or more sensing (input) conditions and in turn provide the one or more perceivable output conditions.

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For example, in one embodiment, a toy/product is configured with one or more light emitting diodes (LEDs) that are controlled to provide one or more colors and/or patterns of light as a function of a sensed condition relating to motion and/or impact of the toy/product (e.g., velocity, acceleration, centrifugal force, impact or other measured response). More generally, a toy/product can be thrown, rotated, made to whirl or otherwise move, touched or otherwise impacted, and the toy/product can be configured to react as a function of velocity, acceleration, centrifugal force, impact or other

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measured response by producing one or more conditions that may be sensed by a user/observer.

It should be appreciated that all combinations of the foregoing concepts and additional concepts discussed in greater detail below are contemplated as being part of the inventive subject matter disclosed herein. In particular, all combinations of claimed
5 subject matter appearing at the end of this disclosure are contemplated as being part of the inventive subject matter disclosed herein.

As used herein for purposes of the present disclosure, the term “LED” should be understood to include any electroluminescent diode or other type of carrier injection /
10 junction-based system that is capable of generating radiation in response to an electric signal. Thus, the term LED includes, but is not limited to, various semiconductor-based structures that emit light in response to current, light emitting polymers, electroluminescent strips, and the like.

In particular, the term LED refers to light emitting diodes of all types (including
15 semi-conductor and organic light emitting diodes) that may be configured to generate radiation in one or more of the infrared spectrum, ultraviolet spectrum, and various portions of the visible spectrum (generally including radiation wavelengths from approximately 400 nanometers to approximately 700 nanometers). Some examples of LEDs include, but are not limited to, various types of infrared LEDs, ultraviolet LEDs,
20 red LEDs, blue LEDs, green LEDs, yellow LEDs, amber LEDs, orange LEDs, and white LEDs (discussed further below). It also should be appreciated that LEDs may be configured to generate radiation having various bandwidths for a given spectrum (e.g., narrow bandwidth, broad bandwidth).

For example, one implementation of an LED configured to generate essentially
25 white light (e.g., a white LED) may include a number of dies which respectively emit different spectra of electroluminescence that, in combination, mix to form essentially white light. In another implementation, a white light LED may be associated with a phosphor material that converts electroluminescence having a first spectrum to a different second spectrum. In one example of this implementation, electroluminescence
30 having a relatively short wavelength and narrow bandwidth spectrum “pumps” the phosphor material, which in turn radiates longer wavelength radiation having a somewhat broader spectrum.

It should also be understood that the term LED does not limit the physical and/or electrical package type of an LED. For example, as discussed above, an LED may refer to a single light emitting device having multiple dies that are configured to respectively emit different spectra of radiation (e.g., that may or may not be individually

5 controllable). Also, an LED may be associated with a phosphor that is considered as an integral part of the LED (e.g., some types of white LEDs). In general, the term LED may refer to packaged LEDs, non-packaged LEDs, surface mount LEDs, chip-on-board LEDs, T-package mount LEDs, radial package LEDs, power package LEDs, LEDs including some type of encasement and/or optical element (e.g., a diffusing lens), etc.

10 The term “light source” should be understood to refer to any one or more of a variety of radiation sources, including, but not limited to, LED-based sources (including one or more LEDs as defined above), incandescent sources (e.g., filament lamps, halogen lamps), fluorescent sources, phosphorescent sources, high-intensity discharge sources (e.g., sodium vapor, mercury vapor, and metal halide lamps), lasers, other types of

15 electroluminescent sources, pyro-luminescent sources (e.g., flames), candle-luminescent sources (e.g., gas mantles, carbon arc radiation sources), photo-luminescent sources (e.g., gaseous discharge sources), cathode luminescent sources using electronic saturation, galvano-luminescent sources, crystallo-luminescent sources, kine-luminescent sources, thermo-luminescent sources, triboluminescent sources , sonoluminescent sources,

20 radioluminescent sources, and luminescent polymers.

A given light source may be configured to generate electromagnetic radiation within the visible spectrum, outside the visible spectrum, or a combination of both. Hence, the terms “light” and “radiation” are used interchangeably herein. Additionally, a light source may include as an integral component one or more filters (e.g., color filters),

25 lenses, or other optical components. Also, it should be understood that light sources may be configured for a variety of applications, including, but not limited to, indication and/or illumination. An “illumination source” is a light source that is particularly configured to generate radiation having a sufficient intensity to effectively illuminate an interior or exterior space.

30 The term “spectrum” should be understood to refer to any one or more frequencies (or wavelengths) of radiation produced by one or more light sources. Accordingly, the term “spectrum” refers to frequencies (or wavelengths) not only in the

visible range, but also frequencies (or wavelengths) in the infrared, ultraviolet, and other areas of the overall electromagnetic spectrum. Also, a given spectrum may have a relatively narrow bandwidth (essentially few frequency or wavelength components) or a relatively wide bandwidth (several frequency or wavelength components having various
5 relative strengths). It should also be appreciated that a given spectrum may be the result of a mixing of two or more other spectra (e.g., mixing radiation respectively emitted from multiple light sources).

For purposes of this disclosure, the term “color” is used interchangeably with the term “spectrum.” However, the term “color” generally is used to refer primarily to a
10 property of radiation that is perceivable by an observer (although this usage is not intended to limit the scope of this term). Accordingly, the terms “different colors” implicitly refer to multiple spectra having different wavelength components and/or bandwidths. It also should be appreciated that the term “color” may be used in connection with both white and non-white light.

15 The term “color temperature” generally is used herein in connection with white light, although this usage is not intended to limit the scope of this term. Color temperature essentially refers to a particular color content or shade (e.g., reddish, bluish) of white light. The color temperature of a given radiation sample conventionally is characterized according to the temperature in degrees Kelvin (K) of a black body radiator that radiates essentially the same spectrum as the radiation sample in question. The color
20 temperature of white light generally falls within a range of from approximately 700 degrees K (generally considered the first visible to the human eye) to over 10,000 degrees K.

Lower color temperatures generally indicate white light having a more significant
25 red component or a “warmer feel,” while higher color temperatures generally indicate white light having a more significant blue component or a “cooler feel.” By way of example, fire has a color temperature of approximately 1,800 degrees K, a conventional incandescent bulb has a color temperature of approximately 2848 degrees K, early morning daylight has a color temperature of approximately 3,000 degrees K, and
30 overcast midday skies have a color temperature of approximately 10,000 degrees K. A color image viewed under white light having a color temperature of approximately 3,000 degree K has a relatively reddish tone, whereas the same color image viewed under white

light having a color temperature of approximately 10,000 degrees K has a relatively bluish tone.

The terms “lighting unit” and “lighting fixture” are used interchangeably herein to refer to an apparatus including one or more light sources of same or different types. A
5 given lighting unit may have any one of a variety of mounting arrangements for the light source(s), enclosure/housing arrangements and shapes, and/or electrical and mechanical connection configurations. Additionally, a given lighting unit optionally may be associated with (e.g., include, be coupled to and/or packaged together with) various other components (e.g., control circuitry) relating to the operation of the light source(s). An
10 “LED-based lighting unit” refers to a lighting unit that includes one or more LED-based light sources as discussed above, alone or in combination with other non LED-based light sources.

The terms “processor” or “controller” are used herein interchangeably to describe various apparatus relating to the operation of one or more light sources. A
15 processor or controller can be implemented in numerous ways, such as with dedicated hardware, using one or more microprocessors that are programmed using software (e.g., microcode) to perform the various functions discussed herein, or as a combination of dedicated hardware to perform some functions and programmed microprocessors and associated circuitry to perform other functions.

20 In various implementations, a processor or controller may be associated with one or more storage media (generically referred to herein as “memory,” e.g., volatile and non-volatile computer memory such as RAM, PROM, EPROM, and EEPROM, floppy disks, compact disks, optical disks, magnetic tape, etc.). In some implementations, the storage media may be encoded with one or more programs that, when executed on one or
25 more processors and/or controllers, perform at least some of the functions discussed herein. Various storage media may be fixed within a processor or controller or may be transportable, such that the one or more programs stored thereon can be loaded into a processor or controller so as to implement various aspects of the present invention discussed herein. The terms “program” or “computer program” are used herein in a
30 generic sense to refer to any type of computer code (e.g., software or microcode) that can be employed to program one or more processors or controllers.

The term “addressable” is used herein to refer to a device (e.g., a light source in general, a lighting unit or fixture, a controller or processor associated with one or more light sources or lighting units, other non-lighting related devices, etc.) that is configured to receive information (e.g., data) intended for multiple devices, including itself, and to selectively respond to particular information intended for it. The term “addressable” often is used in connection with a networked environment (or a “network,” discussed further below), in which multiple devices are coupled together via some communications medium or media.

In one network implementation, one or more devices coupled to a network may serve as a controller for one or more other devices coupled to the network (e.g., in a master / slave relationship). In another implementation, a networked environment may include one or more dedicated controllers that are configured to control one or more of the devices coupled to the network. Generally, multiple devices coupled to the network each may have access to data that is present on the communications medium or media; however, a given device may be “addressable” in that it is configured to selectively exchange data with (i.e., receive data from and/or transmit data to) the network, based, for example, on one or more particular identifiers (e.g., “addresses”) assigned to it.

The term “network” as used herein refers to any interconnection of two or more devices (including controllers or processors) that facilitates the transport of information (e.g. for device control, data storage, data exchange, etc.) between any two or more devices and/or among multiple devices coupled to the network. As should be readily appreciated, various implementations of networks suitable for interconnecting multiple devices may include any of a variety of network topologies and employ any of a variety of communication protocols. Additionally, in various networks according to the present invention, any one connection between two devices may represent a dedicated connection between the two systems, or alternatively a non-dedicated connection. In addition to carrying information intended for the two devices, such a non-dedicated connection may carry information not necessarily intended for either of the two devices (e.g., an open network connection). Furthermore, it should be readily appreciated that various networks of devices as discussed herein may employ one or more wireless, wire/cable, and/or fiber optic links to facilitate information transport throughout the network.

The term “user interface” as used herein refers to an interface between a human user or operator and one or more devices that enables communication between the user and the device(s). Examples of user interfaces that may be employed in various implementations of the present invention include, but are not limited to, switches, potentiometers, buttons, dials, sliders, a mouse, keyboard, keypad, various types of game controllers (e.g., joysticks), track balls, display screens, various types of graphical user interfaces (GUIs), touch screens, microphones and other types of sensors that may receive some form of human-generated stimulus and generate a signal in response thereto.

The following patents and patent applications are hereby incorporated herein by reference:

U.S. Patent No. 6,016,038, issued January 18, 2000, entitled “Multicolored LED Lighting Method and Apparatus;”

U.S. Patent No. 6,211,626, issued April 3, 2001 to Lys et al, entitled “Illumination Components;”

U.S. Patent No. 6,608,453, issued August 19, 2003, entitled “Methods and Apparatus for Controlling Devices in a Networked Lighting System;”

U.S. Patent No. 6,548,967, issued April 15, 2003, entitled “Universal Lighting Network Methods and Systems;”

U.S. Patent Application Serial No. 09/886,958, filed June 21, 2001, entitled “Method and Apparatus for Controlling a Lighting System in Response to an Audio Input;”

U.S. Patent Application Serial No. 10/078,221, filed February 19, 2002, entitled “Systems and Methods for Programming Illumination Devices;”

U.S. Patent Application Serial No. 09/344,699, filed June 25, 1999, entitled “Method for Software Driven Generation of Multiple Simultaneous High Speed Pulse Width Modulated Signals;”

U.S. Patent Application Serial No. 09/805,368, filed March 13, 2001, entitled “Light-Emitting Diode Based Products;”

U.S. Patent Application Serial No. 09/716,819, filed November 20, 2000, entitled “Systems and Methods for Generating and Modulating Illumination Conditions;”

U.S. Patent Application Serial No. 09/675,419, filed September 29, 2000, entitled
“Systems and Methods for Calibrating Light Output by Light-Emitting Diodes;”

U.S. Patent Application Serial No. 09/870,418, filed May 30, 2001, entitled “A
Method and Apparatus for Authoring and Playing Back Lighting Sequences;”

5 U.S. Patent Application Serial No. 10/045,629, filed October 25, 2001, entitled
“Methods and Apparatus for Controlling Illumination;”

U.S. Patent Application Serial No. 10/158,579, filed May 30, 2002, entitled
“Methods and Apparatus for Controlling Devices in a Networked Lighting System;”

10 U.S. Patent Application Serial No. 10/163,085, filed June 5, 2002, entitled
“Systems and Methods for Controlling Programmable Lighting Systems;”

U.S. Patent Application Serial No. 10/325,635, filed December 19, 2002, entitled
“Controlled Lighting Methods and Apparatus;” and

U.S. Patent Application Serial No. 10/360,594, filed February 6, 2003, entitled
“Controlled Lighting Methods and Apparatus.”

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Brief Description of the Drawings

Fig. 1 is a diagram illustrating a lighting unit according to one embodiment of the
invention;

20 Fig. 2 is a diagram of a toy configured with control capability, one or more light
sources similar to those discussed in connection with Fig. 1, and/or one or more sound-
producing output devices, according to one embodiment of the invention;

Fig. 3 is a diagram of a user whirling the toy of Fig. 2 about their head; and

Fig. 4 is a diagram illustrating a networked lighting system that may be
implemented with multiple toys/products according to one embodiment of the invention.

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Detailed Description

The present invention is directed generally to various toys or other consumer
products that provide at least one type of perceivable phenomenon that may be sensed by
a human (e.g., light and/or sound) to facilitate some form of interactivity between the
30 toy/product and one or more users/observers of the toy/product.

For example, according to one aspect of the present invention, toys and consumer
products are configured to provide one or more output modalities/conditions to facilitate

enhanced interactivity with users/observers. Examples of outputs can include, but are not limited to, one or more of sound(s), music, light, color, motion, actuation. In another embodiment, a toy or consumer product also may be configured to monitor one or more sensing (input) conditions and in turn provide one or more output conditions. Examples
5 of inputs can include, but are not limited to, one or more of temperature, motion, sound, pressure, electromagnetic spectrum, acoustic input, proximity, motion detection, and position. In one aspect of this embodiment, one or more particular output modalities are selected based at least in part on one or more particular input conditions.

For example, in one implementation, a toy/product is configured with one or
10 more light emitting diodes (LEDs) that are controlled to provide one or more colors and/or patterns of light as a function of a sensed condition relating to motion and/or impact of the toy/product (e.g., velocity, acceleration, centrifugal force, impact or other measured response). In general, according to various embodiments, a toy/product can be thrown, rotated, made to whirl or otherwise move, touched or otherwise impacted, and
15 the toy/product can be configured to react as a function of velocity, acceleration, centrifugal force, impact or other measured response by producing one or more conditions that may be sensed by a user/observer.

Various embodiments of the present invention are described below, including certain embodiments relating particularly to LED-based light sources. It should be
20 appreciated, however, that the present invention is not limited to any particular manner of implementation, and that the various embodiments discussed explicitly herein are primarily for purposes of illustration. For example, the various concepts discussed herein may be suitably implemented in a variety of environments involving LED-based light sources, other types of light sources not including LEDs, environments that involve
25 both LEDs and other types of light sources in combination, and environments that involve non-lighting-related devices alone or in combination with various types of light sources.

Fig. 1 illustrates one example of a lighting unit 100 that may serve as a light
producing device in a toy/consumer product according to one embodiment of the present
30 invention. Some examples of LED-based lighting units similar to those that are described below in connection with Fig. 1 may be found, for example, in U.S. Patent No. 6,016,038, issued January 18, 2000 to Mueller et al., entitled "Multicolored LED

Lighting Method and Apparatus,” and U.S. Patent No. 6,211,626, issued April 3, 2001 to Lys et al, entitled “Illumination Components,” which patents are both hereby incorporated herein by reference.

In various embodiments of the present invention, the lighting unit 100 shown in
5 Fig. 1 may be used alone or together with other similar lighting units in a system of lighting units (e.g., as discussed further below in connection with Fig. 4).

One or more lighting units similar to that described in connection with Fig. 1 may be implemented in a variety of products including, but not limited to, various forms of light modules or bulbs having various shapes and electrical/mechanical coupling
10 arrangements (including replacement or “retrofit” modules or bulbs adapted for use in conventional sockets or fixtures), as well as a variety of consumer and/or household products (e.g., night lights, toys, games or game components, entertainment components or systems, utensils, appliances, kitchen aids, cleaning products, etc.).

In one embodiment, the lighting unit 100 shown in Fig. 1 may include one or
15 more light sources 104A, 104B, and 104C (shown collectively as 104), wherein one or more of the light sources may be an LED-based light source that includes one or more light emitting diodes (LEDs). In one aspect of this embodiment, any two or more of the light sources 104A, 104B, and 104C may be adapted to generate radiation of different colors (e.g. red, green, and blue, respectively). Although Fig. 1 shows three light sources
20 104A, 104B, and 104C, it should be appreciated that the lighting unit is not limited in this respect, as different numbers and various types of light sources (all LED-based light sources, LED-based and non-LED-based light sources in combination, etc.) adapted to generate radiation of a variety of different colors, including essentially white light, may be employed in the lighting unit 100, as discussed further below.

As shown in Fig. 1, the lighting unit 100 also may include a processor 102 that is
25 configured to output one or more control signals to drive the light sources 104A, 104B, and 104C so as to generate various intensities of light from the light sources. For example, in one implementation, the processor 102 may be configured to output at least one control signal for each light source so as to independently control the intensity of
30 light generated by each light source. Some examples of control signals that may be generated by the processor to control the light sources include, but are not limited to, pulse modulated signals, pulse width modulated signals (PWM), pulse amplitude

modulated signals (PAM), pulse code modulated signals (PCM) analog control signals (e.g., current control signals, voltage control signals), combinations and/or modulations of the foregoing signals, or other control signals. In one aspect, the processor 102 may control other dedicated circuitry (not shown in Fig. 1) which in turn controls the light
5 sources so as to vary their respective intensities.

In one embodiment of the lighting unit 100, one or more of the light sources 104A, 104B, and 104C shown in Fig. 1 may include a group of multiple LEDs or other types of light sources (e.g., various parallel and/or serial connections of LEDs or other types of light sources) that are controlled together by the processor 102. Additionally, it
10 should be appreciated that one or more of the light sources 104A, 104B, and 104C may include one or more LEDs that are adapted to generate radiation having any of a variety of spectra (i.e., wavelengths or wavelength bands), including, but not limited to, various visible colors (including essentially white light), various color temperatures of white light, ultraviolet, or infrared. LEDs having a variety of spectral bandwidths (e.g., narrow
15 band, broader band) may be employed in various implementations of the lighting unit 100.

In another aspect of the lighting unit 100 shown in Fig. 1, the lighting unit 100 may be constructed and arranged to produce a wide range of variable color radiation. For example, the lighting unit 100 may be particularly arranged such that the processor-
20 controlled variable intensity light generated by two or more of the light sources combines to produce a mixed colored light (including essentially white light having a variety of color temperatures). In particular, the color (or color temperature) of the mixed colored light may be varied by varying one or more of the respective intensities of the light sources (e.g., in response to one or more control signals output by the processor 102).
25 Furthermore, the processor 102 may be particularly configured (e.g., programmed) to provide control signals to one or more of the light sources so as to generate a variety of static or time-varying (dynamic) multi-color (or multi-color temperature) lighting effects.

Thus, the lighting unit 100 may include a wide variety of colors of LEDs in various combinations, including two or more of red, green, and blue LEDs to produce a
30 color mix, as well as one or more other LEDs to create varying colors and color temperatures of white light. For example, red, green and blue can be mixed with amber, white, UV, orange, IR or other colors of LEDs. Such combinations of differently

colored LEDs in the lighting unit 100 can facilitate accurate reproduction of a host of desirable spectrums of lighting conditions, examples of which includes, but are not limited to, a variety of outside daylight equivalents at different times of the day, various interior lighting conditions, lighting conditions to simulate a complex multicolored background, and the like. Other desirable lighting conditions can be created by removing particular pieces of spectrum that may be specifically absorbed, attenuated or reflected in certain environments. Water, for example tends to absorb and attenuate most non-blue and non-green colors of light, so underwater applications may benefit from lighting conditions that are tailored to emphasize or attenuate some spectral elements relative to others.

As shown in Fig. 1, the lighting unit 100 also may include a memory 114 to store various information. For example, the memory 114 may be employed to store one or more lighting programs for execution by the processor 102 (e.g., to generate one or more control signals for the light sources), as well as various types of data useful for generating variable color radiation (e.g., calibration information, discussed further below). The memory 114 also may store one or more particular identifiers (e.g., a serial number, an address, etc.) that may be used either locally or on a system level to identify the lighting unit 100. In various embodiments, such identifiers may be pre-programmed by a manufacturer, for example, and may be either alterable or non-alterable thereafter (e.g., via some type of user interface located on the lighting unit, via one or more data or control signals received by the lighting unit, etc.). Alternatively, such identifiers may be determined at the time of initial use of the lighting unit in the field, and again may be alterable or non-alterable thereafter.

One issue that may arise in connection with controlling multiple light sources in the lighting unit 100 of Fig. 1, and controlling multiple lighting units 100 in a lighting system (e.g., as discussed below in connection with Fig. 4), relates to potentially perceptible differences in light output between substantially similar light sources. For example, given two virtually identical light sources being driven by respective identical control signals, the actual intensity of light output by each light source may be perceptibly different. Such a difference in light output may be attributed to various factors including, for example, slight manufacturing differences between the light sources, normal wear and tear over time of the light sources that may differently alter the

respective spectrums of the generated radiation, etc. For purposes of the present discussion, light sources for which a particular relationship between a control signal and resulting intensity are not known are referred to as “uncalibrated” light sources.

The use of one or more uncalibrated light sources in the lighting unit 100 shown
5 in Fig. 1 may result in generation of light having an unpredictable, or “uncalibrated,” color or color temperature. For example, consider a first lighting unit including a first uncalibrated red light source and a first uncalibrated blue light source, each controlled by a corresponding control signal having an adjustable parameter in a range of from zero to 255 (0-255). For purposes of this example, if the red control signal is set to zero, blue
10 light is generated, whereas if the blue control signal is set to zero, red light is generated. However, if both control signals are varied from non-zero values, a variety of perceptibly different colors may be produced (e.g., in this example, at very least, many different shades of purple are possible). In particular, perhaps a particular desired color (e.g., lavender) is given by a red control signal having a value of 125 and a blue control signal
15 having a value of 200.

Now consider a second lighting unit including a second uncalibrated red light source substantially similar to the first uncalibrated red light source of the first lighting unit, and a second uncalibrated blue light source substantially similar to the first uncalibrated blue light source of the first lighting unit. As discussed above, even if both
20 of the uncalibrated red light sources are driven by respective identical control signals, the actual intensity of light output by each red light source may be perceptibly different. Similarly, even if both of the uncalibrated blue light sources are driven by respective identical control signals, the actual intensity of light output by each blue light source may be perceptibly different.

25 With the foregoing in mind, it should be appreciated that if multiple uncalibrated light sources are used in combination in lighting units to produce a mixed colored light as discussed above, the observed color (or color temperature) of light produced by different lighting units under identical control conditions may be perceptibly different. Specifically, consider again the “lavender” example above; the “first lavender” produced
30 by the first lighting unit with a red control signal of 125 and a blue control signal of 200 indeed may be perceptibly different than a “second lavender” produced by the second lighting unit with a red control signal of 125 and a blue control signal of 200. More

generally, the first and second lighting units generate uncalibrated colors by virtue of their uncalibrated light sources.

In view of the foregoing, in one embodiment of the present invention, the lighting unit 100 includes calibration means to facilitate the generation of light having a calibrated (e.g., predictable, reproducible) color at any given time. In one aspect, the calibration means is configured to adjust the light output of at least some light sources of the lighting unit so as to compensate for perceptible differences between similar light sources used in different lighting units.

For example, in one embodiment, the processor 102 of the lighting unit 100 is configured to control one or more of the light sources 104A, 104B, and 104C so as to output radiation at a calibrated intensity that substantially corresponds in a predetermined manner to a control signal for the light source(s). As a result of mixing radiation having different spectra and respective calibrated intensities, a calibrated color is produced. In one aspect of this embodiment, at least one calibration value for each light source is stored in the memory 114, and the processor is programmed to apply the respective calibration values to the control signals for the corresponding light sources so as to generate the calibrated intensities.

In one aspect of this embodiment, one or more calibration values may be determined once (e.g., during a lighting unit manufacturing/testing phase) and stored in the memory 114 for use by the processor 102. In another aspect, the processor 102 may be configured to derive one or more calibration values dynamically (e.g. from time to time) with the aid of one or more photosensors, for example. In various embodiments, the photosensor(s) may be one or more external components coupled to the lighting unit, or alternatively may be integrated as part of the lighting unit itself. A photosensor is one example of a signal source that may be integrated or otherwise associated with the lighting unit 100, and monitored by the processor 102 in connection with the operation of the lighting unit. Other examples of such signal sources are discussed further below, in connection with the signal source 124 shown in Fig. 1.

One exemplary method that may be implemented by the processor 102 to derive one or more calibration values includes applying a reference control signal to a light source, and measuring (e.g., via one or more photosensors) an intensity of radiation thus generated by the light source. The processor may be programmed to then make a

comparison of the measured intensity and at least one reference value (e.g., representing an intensity that nominally would be expected in response to the reference control signal). Based on such a comparison, the processor may determine one or more calibration values for the light source. In particular, the processor may derive a calibration value such that, when applied to the reference control signal, the light source outputs radiation having an intensity the corresponds to the reference value (i.e., the “expected” intensity).

In various aspects, one calibration value may be derived for an entire range of control signal/output intensities for a given light source. Alternatively, multiple calibration values may be derived for a given light source (i.e., a number of calibration value “samples” may be obtained) that are respectively applied over different control signal/output intensity ranges, to approximate a nonlinear calibration function in a piecewise linear manner.

In another aspect, as also shown in Fig. 1, the lighting unit 100 optionally may include one or more user interfaces 118 that are provided to facilitate any of a number of user-selectable settings or functions (e.g., generally controlling the light output of the lighting unit 100, changing and/or selecting various pre-programmed lighting effects to be generated by the lighting unit, changing and/or selecting various parameters of selected lighting effects, setting particular identifiers such as addresses or serial numbers for the lighting unit, etc.). In various embodiments, the communication between the user interface 118 and the lighting unit may be accomplished through wire or cable, or wireless transmission.

In one implementation, the processor 102 of the lighting unit monitors the user interface 118 and controls one or more of the light sources 104A, 104B, and 104C based at least in part on a user’s operation of the interface. For example, the processor 102 may be configured to respond to operation of the user interface by originating one or
s more control signals for controlling one or more of the light sources. Alternatively, the processor 102 may be configured to respond by selecting one or more pre-programmed control signals stored in memory, modifying control signals generated by executing a lighting program, selecting and executing a new lighting program from memory, or otherwise affecting the radiation generated by one or more of the light sources.

In particular, in one implementation, the user interface 118 may constitute one or more switches (e.g., a standard wall switch) that interrupt power to the processor 102. In one aspect of this implementation, the processor 102 is configured to monitor the power as controlled by the user interface, and in turn control one or more of the light sources 104A, 104B, and 104C based at least in part on a duration of a power interruption caused by operation of the user interface. As discussed above, the processor may be particularly configured to respond to a predetermined duration of a power interruption by, for example, selecting one or more pre-programmed control signals stored in memory, modifying control signals generated by executing a lighting program, selecting and executing a new lighting program from memory, or otherwise affecting the radiation generated by one or more of the light sources.

Fig. 1 also illustrates that the lighting unit 100 may be configured to receive one or more signals 122 from one or more other signal sources 124. In one implementation, the processor 102 of the lighting unit may use the signal(s) 122, either alone or in combination with other control signals (e.g., signals generated by executing a lighting program, one or more outputs from a user interface, etc.), so as to control one or more of the light sources 104A, 104B and 104C in a manner similar to that discussed above in connection with the user interface.

Examples of the signal(s) 122 that may be received and processed by the processor 102 include, but are not limited to, one or more audio signals, video signals, power signals, various types of data signals, signals representing information obtained from a network (e.g., the Internet), signals representing one or more detectable/sensed conditions, signals from lighting units, signals consisting of modulated light, etc. In various implementations, the signal source(s) 124 may be located remotely from the lighting unit 100, or included as a component of the lighting unit. For example, in one embodiment, a signal from one lighting unit 100 could be sent over a network to another lighting unit 100.

Some examples of a signal source 124 that may be employed in, or used in connection with, the lighting unit 100 of Fig. 1 include any of a variety of sensors or transducers that generate one or more signals 122 in response to some stimulus. Examples of such sensors include, but are not limited to, various types of environmental condition sensors, such as thermally sensitive (e.g., temperature, infrared) sensors,

humidity sensors, motion sensors, photosensors/light sensors (e.g., sensors that are sensitive to one or more particular spectra of electromagnetic radiation), various types of cameras, sound or vibration sensors or other pressure/force transducers (e.g., microphones, piezoelectric devices, impact sensors), and the like.

5 Additional examples of a signal source 124 include various metering/detection devices that monitor electrical signals or characteristics (e.g., voltage, current, power, resistance, capacitance, inductance, etc.) or chemical/biological characteristics (e.g., acidity, a presence of one or more particular chemical or biological agents, bacteria, etc.) and provide one or more signals 122 based on measured values of the signals or
10 characteristics. Yet other examples of a signal source 124 include various types of scanners, image recognition systems, voice or other sound recognition systems, artificial intelligence and robotics systems, and the like. A signal source 124 could also be a lighting unit 100, a processor 102, or any one of many available signal generating devices, such as media players, MP3 players, computers, DVD players, CD players,
15 television signal sources, camera signal sources, microphones, speakers, telephones, cellular phones, instant messenger devices, SMS devices, wireless devices, personal organizer devices, and many others.

In one embodiment, the lighting unit 100 shown in Fig. 1 also may include one or more optical elements 130 to optically process the radiation generated by the light sources 104A, 104B, and 104C. For example, one or more optical elements may be configured so as to change one or both of a spatial distribution and a propagation direction of the generated radiation. In particular, one or more optical elements may be configured to change a diffusion angle of the generated radiation. In one aspect of this embodiment, one or more optical elements 130 may be particularly configured to variably change one or both of a spatial distribution and a propagation direction of the generated radiation (e.g., in response to some electrical and/or mechanical stimulus). Examples of optical elements that may be included in the lighting unit 100 include, but are not limited to, reflective materials, refractive materials, translucent materials, filters, lenses, mirrors, and fiber optics. The optical element 130 also may include a phosphorescent material, luminescent material, or other material capable of responding to or interacting with the generated radiation.

As also shown in Fig. 1, the lighting unit 100 may include one or more communication ports 120 to facilitate coupling of the lighting unit 100 to any of a variety of other devices. For example, one or more communication ports 120 may facilitate coupling multiple lighting units together as a networked lighting system, in which at least some of the lighting units are addressable (e.g., have particular identifiers or addresses) and are responsive to particular data transported across the network.

In particular, in a networked lighting system environment, as discussed in greater detail further below (e.g., in connection with Fig. 4), as data is communicated via the network, the processor 102 of each lighting unit coupled to the network may be configured to be responsive to particular data (e.g., lighting control commands) that
5 pertain to it (e.g., in some cases, as dictated by the respective identifiers of the networked lighting units). Once a given processor identifies particular data intended for it, it may read the data and, for example, change the lighting conditions produced by its light sources according to the received data (e.g., by generating appropriate control signals to the light sources). In one aspect, the memory 114 of each lighting unit coupled to the
10 network may be loaded, for example, with a table of lighting control signals that correspond with data the processor 102 receives. Once the processor 102 receives data from the network, the processor may consult the table to select the control signals that correspond to the received data, and control the light sources of the lighting unit accordingly.

15 In one aspect of this embodiment, the processor 102 of a given lighting unit, whether or not coupled to a network, may be configured to interpret lighting instructions/data that are received in a DMX protocol (as discussed, for example, in U.S. Patents 6,016,038 and 6,211,626), which is a lighting command protocol conventionally employed in the lighting industry for some programmable lighting applications.
20 However, it should be appreciated that lighting units suitable for purposes of the present invention are not limited in this respect, as lighting units according to various embodiments may be configured to be responsive to other types of communication protocols so as to control their respective light sources.

In one embodiment, the lighting unit 100 of Fig. 1 may include and/or be coupled
25 to one or more power sources 108. In various aspects, examples of power source(s) 108 include, but are not limited to, AC power sources, DC power sources, batteries, solar-

based power sources, thermoelectric or mechanical-based power sources and the like. Additionally, in one aspect, the power source(s) 108 may include or be associated with one or more power conversion devices that convert power received by an external power source to a form suitable for operation of the lighting unit 100.

5 While not shown explicitly in Fig. 1, the lighting unit 100 may be implemented in any one of several different structural configurations according to various embodiments of the present invention. Examples of such configurations include, but are not limited to, an essentially linear or curvilinear configuration, a circular configuration, an oval configuration, a rectangular configuration, combinations of the foregoing, various other
10 geometrically shaped configurations, various two or three dimensional configurations, and the like.

A given lighting unit also may have any one of a variety of mounting arrangements for the light source(s), enclosure/housing arrangements and shapes to partially or fully enclose the light sources, and/or electrical and mechanical connection
15 configurations. In particular, a lighting unit may be configured as a replacement or “retrofit” to engage electrically and mechanically in a conventional socket or fixture arrangement (e.g., an Edison-type screw socket, a halogen fixture arrangement, a fluorescent fixture arrangement, etc.).

Additionally, one or more optical elements as discussed above may be partially or
20 fully integrated with an enclosure/housing arrangement for the lighting unit. Furthermore, a given lighting unit optionally may be associated with (e.g., include, be coupled to and/or packaged together with) various other components (e.g., control circuitry such as the processor and/or memory, one or more sensors/transducers/signal sources, user interfaces, displays, power sources, power conversion devices, etc.) relating
25 to the operation of the light source(s).

Fig. 2 illustrates an example of a toy 300 according to one embodiment of the present invention, showing an overall view of a housing with a variety of components. In one aspect, the housing is equipped with an optional tether 302 to facilitate handling by a user. In this embodiment, the toy is implemented with a processor 102 as discussed
30 above, at least one sensor 124, and at least one output device. For example, in one implementation, the output device may be at least one speaker 304 and/or at least one LED-based light source 104 as discussed above in connection with Fig. 1. In general,

one or both of light and or sound-producing output devices may be controlled in a manner similar to that described above in connection with the lighting unit 100 shown in Fig. 1.

In various aspects, one or more output devices of the toy 300 are configured to be responsive to one or more sensed conditions detected by one or more sensors 124. For example, in one implementation, as shown in Fig. 3, a user whirls the toy 300 about their head, and this whirling motion is detected to provide one or more outputs (e.g., light and/or sound). The toy may employ a power switch or other type of user interface to turn it on or off or, alternatively, the toy may always be in a “standby mode” wherein one or more sensed conditions automatically activate the toy to provide some type of output. Likewise, once activated, the toy may be configured to “shut itself off” or go into a power saving standby mode after a predetermined period without any sensed input condition (e.g., no motion).

Based on using one or both of light and sound as an output condition, the toy may be configured to provide a number of output modalities based on one or more sensed input conditions. For example, as the toy is swung around faster and faster, a sound-based output device may be configured to produce a tone that rises in pitch or volume or changes the pattern of tones. Similarly, as the toy is swung faster and faster, a light-producing output device (e.g., the LED-based light source 104) may be configured to generate colors that shift from blue to green to red or some other combination / sequence of colors. In another example, as the toy is swung faster and faster, a light-producing output device may be configured to produce a multicolored light pattern that shifts across the surface of the device causing a shifting rainbow pattern as the centrifugal force reaches a preset value.

In yet other examples, as the toy is swung rapidly and then released, a sound-producing output device may produce a shrill high-pitched sound like a falling bomb that turns into the sound of an explosion when the toy hits the ground or another object. Likewise, a light-producing output device may be configured such that bright flashes and patterns of light accompany the toy movement and impact.

More generally, the light-producing and/or sound-producing output device(s) can be used to create colors or patterns of colors and sounds or patterns of sounds to indicate different speeds or forces. In one embodiment, the toy may be equipped with a three-

axis motion sensor, such as those available from Analog Devices (such as the ADXL family of products) or Motorola, for measuring and reporting forces, motion, impact etc. This type of sensor commonly is used in force-responding joysticks and video game controllers. This sensor can provide inertial and impact force information in all three
5 axes. Multiple such units can also provide spin and orientation information. In one example using this or some other type of motion/velocity sensor, a Doppler shift effect may be created in both sound and light in response to velocity of the toy.

In other examples, sound and/or light patterns may be generated in response to changes in ambient noise.

10 In another embodiment, built-in functions to react to sound and other sensed inputs can be added, changed and uploaded to the device from a digital music player, PDA or computer.

In another embodiment, as the toy/product is tapped with fingers or a stick, the toy/product can operate like a drum machine but also give off color. Touch sensitive
15 pads can be located around the surface to give different sounds.

In another embodiment, a sound-producing output device may include a speaker/music system with a ported bass unit to give high quality deep sounds like the small Bose® wave radio products.

20 In another embodiment, the toy/product can have an audio input to couple light shows to music.

In another embodiment, multiple toys/products can be configured to communicate with each other to give more complex and sophisticated and interesting sound and light effects. For example, Fig. 4 illustrates an example of a networked lighting system 200 according to one embodiment of the present invention. In the
25 embodiment of Fig. 4, a number of lighting units 100, similar to those discussed above in connection with Fig. 1, are coupled together to form the networked lighting system. In one implementation, one or more lighting units 100 may be arranged in connection with (e.g., contained in) one of a number of toys/products such that a collection of toys/products employing multiple lighting units 100 may produce coordinated lighting
30 effects. It should be appreciated, however, that the particular configuration and arrangement of lighting units shown in Fig. 4 is for purposes of illustration only, and that the invention is not limited to the particular system topology shown in Fig. 4.

Additionally, while not shown explicitly in Fig. 4, it should be appreciated that the networked lighting system 200 may be configured flexibly to include one or more user interfaces, as well as one or more signal sources such as sensors/transducers. For example, one or more user interfaces and/or one or more signal sources such as

5 sensors/transducers (as discussed above in connection with Fig. 1) may be associated with any one or more of the lighting units of the networked lighting system 200. Alternatively (or in addition to the foregoing), one or more user interfaces and/or one or more signal sources may be implemented as “stand alone” components in the networked lighting system 200. Whether stand alone components or particularly associated with
10 one or more lighting units 100, these devices may be “shared” by the lighting units of the networked lighting system. Stated differently, one or more user interfaces and/or one or more signal sources such as sensors/transducers may constitute “shared resources” in the networked lighting system that may be used in connection with controlling any one or more of the lighting units of the system.

15 As shown in the embodiment of Fig. 4, the lighting system 200 may include one or more lighting unit controllers (hereinafter “LUCs”) 208A, 208B, 208C, and 208D, wherein each LUC is responsible for communicating with and generally controlling one or more lighting units 100 coupled to it. Although Fig. 4 illustrates one lighting unit 100 coupled to each LUC, it should be appreciated that the invention is not limited in this
20 respect, as different numbers of lighting units 100 may be coupled to a given LUC in a variety of different configurations (serially connections, parallel connections, combinations of serial and parallel connections, etc.) using a variety of different communication media and protocols.

In the system of Fig. 4, each LUC in turn may be coupled to a central controller
25 202 that is configured to communicate with one or more LUCs. Although Fig. 4 shows four LUCs coupled to the central controller 202 via a generic connection 204 (which may include any number of a variety of conventional coupling, switching and/or networking devices), it should be appreciated that according to various embodiments, different numbers of LUCs may be coupled to the central controller 202. Additionally,
30 according to various embodiments of the present invention, the LUCs and the central controller may be coupled together in a variety of configurations using a variety of different communication media and protocols to form the networked lighting system

200. Moreover, it should be appreciated that the interconnection of LUCs and the central controller, and the interconnection of lighting units to respective LUCs, may be accomplished in different manners (e.g., using different configurations, communication media, and protocols).

5 For example, according to one embodiment of the present invention, the central controller 202 shown in Fig. 4 may be configured to implement wireless Ethernet-based communications with the LUCs, and in turn the LUCs may be configured to implement wireless DMX-based communications with the lighting units 100. In particular, in one aspect of this embodiment, each LUC may be configured as an addressable Ethernet-based controller and accordingly may be identifiable to the central controller 202 via a
10 particular unique address (or a unique group of addresses) using an Ethernet-based protocol. In this manner, the central controller 202 may be configured to support Ethernet communications throughout the network of coupled LUCs, and each LUC may respond to those communications intended for it. In turn, each LUC may communicate
15 lighting control information to one or more lighting units coupled to it, for example, via a DMX protocol, based on the Ethernet communications with the central controller 202.

 More specifically, according to one embodiment, the LUCs 208A, 208B, and 208C shown in Fig. 4 may be configured to be “intelligent” in that the central controller 202 may be configured to communicate higher level commands to the LUCs that need to
20 be interpreted by the LUCs before lighting control information can be forwarded to the lighting units 100. For example, a lighting system operator may want to generate a color changing effect that varies colors from lighting unit to lighting unit in such a way as to generate the appearance of a propagating rainbow of colors (“rainbow chase”), given a particular placement of lighting units with respect to one another. In this example, the
25 operator may provide a simple instruction to the central controller 202 to accomplish this, and in turn the central controller may communicate to one or more LUCs using an Ethernet-based protocol high level command to generate a “rainbow chase.” The command may contain timing, intensity, hue, saturation or other relevant information, for example. When a given LUC receives such a command, it may then interpret the
30 command so as to generate the appropriate lighting control signals which it then communicates using a DMX protocol via any of a variety of signaling techniques (e.g., PWM) to one or more lighting units that it controls.

It should again be appreciated that the foregoing example of using multiple different communication implementations (e.g., Ethernet/DMX) in a lighting system according to one embodiment of the present invention is for purposes of illustration only, and that the invention is not limited to this particular example.

5 Having thus described several illustrative embodiments, it is to be appreciated that various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the spirit and scope of this disclosure. While some examples presented herein involve specific combinations of
10 functions or structural elements, it should be understood that those functions and elements may be combined in other ways according to the present invention to accomplish the same or different objectives. In particular, acts, elements, and features discussed in connection with one embodiment are not intended to be excluded from similar or other roles in other embodiments. Accordingly, the foregoing description and
15 attached drawings are by way of example only, and are not intended to be limiting.